TITLE: Theoretical Impact of a Copper Recovery/Cyanide Regeneration Electrolytic System for the Nickel Plate Mine, B.C.

FINAL REPORT

By: CELEC INC.

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I N D E X

	PAGE NUMBER
EXECUTIVE SUMMARY	1
OBJECTIVES	2
PLANT PROCESS	3
Table I. - Solution Balance	6
Table II. - Chemical Consumption	7
CN Consumption/ SCN Generation	7
Copper Dissolution	8
CELEC TEST SYSTEM	10
Equipment	10
Procedure	10
ELECTROLYTIC TESTWORK	11
Table III.- Experimental Conditions	12
Table IV. - Experimental Results	13
Table V. - Derived Experimental Results	15
Discussion	17
Figures 1.- 18.	20
POWER	38
SYSTEM SIZE	40
PROFITABILITY	41
RECOMMENDATIONS	43
FIGURE A	44

EXECUTIVE SUMMARY

It has been shown, for the Nickel Plate Mine, that 310 Kg/day of copper is available for electrolytic recovery and that 2050 Kg/day of NaSCN equivalent is available for oxidation to cyanide.

Testwork has shown that optimum conditions, for cyanide regeneration and copper recovery, are obtained at a current density of 52 mA/cm^2, a flow rate of 4.6 cm/min., a pH of 10.9, and a temperature of 65° C.

At 65°C copper can be recovered from solution at a cost of 3.1 Kwh/lb and free cyanide can be regenerated in solution at a cost of 0.64 Kwh/lb of sodium cyanide.

At ambient temperature the costs of recovering copper and cyanide increase significantly to 37 Kwh/lb and 3.45 Kwh/lb respectively, indicating that temperature is the most critical parameter affecting the economic viability of the Celec electrolytic cell.

OBJECTIVES

The objectives of the testwork were as follows:-

1. To determine the location and rate of production of copper cyanide, and thiocyanates within the plant.

2. To determine the location and rate of consumption of sodium cyanide within the plant.

3. To determine the optimum operating conditions for the production of free cyanide.

4. To determine the optimum installation of the test electrolytic system proposed for Stage II.

PLANT PROCESS

The plant flowsheet is shown in Fig. A. The crushed material is ground in ball and rod mills with the cyclone overflow being discharged to the pre-aeration tanks.

The grinding mills are fed with solution from three sources:

i) Secondary filtration filtrate
ii) Thickener overflow
iii) Makeup water from the tailings pond

Both the secondary filtration filtrate and thickener overflow contain substantial amounts of free cyanide. Grinding pre-aeration and thickening therefore take place in the presence of free cyanide.

The underflow from the thickener goes to the primary leach tanks. Sodium cyanide solution is added only to the primary leach tanks, no cyanide is added to the secondary leach tanks.

The pulp from the primary leach tanks is fed to the primary filters of which there are seven.

The filtrate from the primary filters is passed through the Merrill-Crowe system to recover gold and silver. The barren solution from the Merrill-Crowe system is used as a spray wash on the primary filters and to repulp the filter cake from the primary filters prior to the pulp entering the secondary leach tanks.

The pulp from the secondary leach tanks is fed to the secondary filters of which there are six.

The filtrate from the secondary filters is recycled back to the grinding mills. The filter cake from the secondary filters is repulped with effluent from the cyanidation plants and then pumped to the tailings pond. The filters are spray washed with reclaim solution from the tailings pond.

The supernatant solution in the tailings pond is recycled through the effluent treatment plant along with any barren bleed.

In order to determine the most efficient placement of an electrolyte copper recovery/cyanide regeneration system in the plant, the following information is required:

i) Consumption of cyanide in different parts of the plant.
ii) Dissolution of copper in different parts of the plant.
iii) Generation of thiocyanate in different parts of the plant.

For the above purposes the plant was divided into the following sections:

A. Grinding mills, pre-aeration tanks and thickener.
B. Primary leach tanks.
C. Primary filtration.
D. Secondary leach tanks and secondary filtration.
E. Effluent treatment and tailings pond.

Solution and ore are transferred between the above points in the following manner:

A - B as a thickened pulp.
B - C as a pulp.

C - D i) as a filter cake, containing entrained pregnant solution and entrained barren wash solution.

ii) as repulped solution.

D - E as a filter cake containing entrained secondary filtrate and entrained reclaim wash water.

D - A as filtrate.

In order to determine the plant processes the following information needs to be determined:

i) Solution flow rates throughout the plant.

ii) Pulp densities.

iii) Volumes of entrained liquids in the filter cakes of the primary and secondary filters.

Solution flow rates and pulp densities were available from historical plant data.

Volume of entrained liquids in primary and secondary filter cakes have been estimated from historical plant data. (see Table I.)

TABLE I- SOLUTION BALANCE

	TONNES SOLIDS	DENSITY	TONNES SOLUTION
GRINDING CIRCUIT			
Mill Feed	2,904	97.55	75
Thickener Feed	2,904	28.05	7,467
Thickener Overflow			5,091
Secondary Filtrate Recycle (Reclaim Backup)			2,301
Thickener Underflow	2,904	55.05	2,376
FILTERING/CYANIDATION			
Primary Filter Feed	2,904	53.05	2,575
Primary Filter Cake	2,904	76.05	915
Primary Leach Sol'n to Preg			2,025
Primary Filter Sprays (Barren) to Preg.			1,268
Total Primary Filtrate to Preg.			3,293
Primary Filter Sprays (Barren) to Repulper			365
Primary Filter Repulp (Barren Sol'n)			1,274
Secondary Filter Feed	2,904	57.05	2,191
Secondary Filter Cake	2,904	72.24	1,116
Secondary Leach Sol'n to Filtrate			1,075
Secondary Filter Sprays to Filtrate			1,180
Total Secondary Filtrate to Grinding, Repulping			2,555
GOLD RECOVERY CIRCUIT:			
Total Volume to Filter Press			3,293
EFFLUENT TREATMENT:			
Bleed to Cyanide Destruction			139
Reclaim			3,270
Repulped Final Tails Slurry	2,904	40.25	4,326

TABLE II - CHEMICAL CONSUMPTION

	A	B	C	D	TOTAL
CYANIDE CONSUMPTION kg/day as NaCN	1295	2107	1187	1364	5953
COPPER DISSOLUTION kg/day	58	120	-54	327	451
THIOCYANATE PRODUCTION kg/day as NaSCN	1510	1728	-1188	-396	1654
CYANIDE CONSUMED BY NaSCN PRODUCTION	913	1045	-	-	1958

CYANIDE CONSUMPTION/THIOCYANATE GENERATION

The cyanide consumed is calculated from the total cyanide present at various stages throughout the plant. As such, the figure is unaffected by the formation of copper, iron or zinc cyanide complexes.

The cyanide consumption figure primarily represents that cyanide that has been changed to cyanate, thiocyanate or has been volatilized.

In the grinding, pre-aeration thickening circuit (point "A", TableII.), 71% of the loss of sodium cyanide can be accounted for by the formation of thiocyanates.

In the primary leach circuit (point "B", Table II.), 50% of the loss of sodium cyanide is accounted for in this way. In this part of the circuit, more cyanide is present as "free" cyanide and is available for hydrolysis to cyanate and for volatilization.

Cyanide and thiocyanates are consumed in the primary filtration stage (point "C", Table II.). The residence time here is very short compared to the residence time in the leach tank and in the grinding, pre-aeration thickening stage. Yet the cyanide consumption is comparable.

The loss of thiocyanates in the filtration stage is difficult to explain. From evaluation of the other parts of the circuit, the thiocyanates seem to be very stable, even through the effluent treatment stage of the plant. A reasonable explanation for the loss of thiocyanates from the filter would be volatilization. Volatilization would also account for the high cyanide consumption at this stage.

Due to the loss of thiocyanates through the primary filtration stage, the amount of thiocyanate available for oxidation to cyanide is only 2050 kg/day, if the solution is taken after primary filtration and before secondary filtration (between points "C" and "D", Table II.).

COPPER DISSOLUTION

The majority of copper dissolution, 327 Kg/day, (72%) occurs in the secondary leach tanks and secondary filtration part of the circuit. (point "D", Table II.)

Of the copper dissolved in this part of the circuit, 160 Kg/day, (49%) is returned to the circuit via the secondary filtrate, the remainder is sent to the tailings pond where it is precipitated. The loss of copper during the primary filtration stage, 54 Kg/day, is likely due to reprecipitation due to cyanide loss and coprecipitation in the Merrill-Crowe process. It is expected that this will drop to 27 Kg/day when the electrolytic cell reduces the overall copper levels and increases the free cyanide levels on the primary filters.

Therefore the total copper available for recovery electrolytically is 310 kg/day, if copper is recovered between the primary and secondary filtration stages, i.e. recovered from the barren solution directly after the Merrill-Crowe process.

CELEC TEST SYSTEM

Equipment:

- PAR Galvanstat/Potentiostat 273
- Masterflex Computerized Drive
- XT Clone
- Electrolytic Cell

The electrolytic cell consisted of the following components:

i) Anode: Titanium sheet with TSR 2000 coating from Eltech Corporation (8.7 cm^2 working area).
ii) Cathode: 1 cm thick carbon felt pad (8.7 cm^2 working area).
iii) Plexiglass Frames to hold and separate the electrodes.
iv) Neoprene gaskets.

The components of the electrolytic cell were pressed and bolted together using a simple 3/4" angle iron frame.

Procedure:

The solution to be tested was recirculated through the electrolytic cell for approximately 12 hours. Samples were taken at intervals and the pH adjusted as required.

Flowrate calibration was carried out prior to the start of each test.

Analytical work was carried out during the tests and immediately upon completion of the tests.

ELECTROLYTIC TESTWORK

Nine tests were carried out at the site on plant barren solutions.

The first four tests concentrated on varying flow and current density as a means of reducing the oxidation of the cyanide. It was clear from these tests that although an increased flow and reduced current density did reduce the oxidation the end result was not good enough.

The second four tests involved stabilization of pH, by the addition of sodium hydroxide pellets as required,variation of current density and of temperature.

These tests showed that at a stable pH of approximately 10.9 and at a lower current density the oxidation of cyanide could be completely eliminated.

The tests also indicated that the performance of the system could be increased by over ten fold in terms of copper recovery and by over five fold in terms of free cyanide generation, by increasing the temperature.

TABLE III - EXPERIMENTAL CONDITIONS

EXPMNT No:	CURRENT DENSITY mA/cm^2	FLOW cm/min	VOLUME Litres	pH	TEMP ^oC
CELEC #1	34.5	9.2	5.0	9.5	25.0
CELEC #2	34.5	9.2	4.9	9.5	25.0
CELEC #3	28.7	4.6	3.0	9.5	25.0
CELEC #4	34.5	4.6	?.5	9.5	25.0
CELEC #5	34.5	4.6	3.0	10.9	25.0
CELEC #6A	40.2	4.6	3.0	11.0	65.0
CELEC #6B	51.7	4.6	3.0	10.9	65.0
CELEC #7	40.2	4.6	3.0	11.1	25.0
CELEC #8	37.4	4.6	3.0	10.9	25.0

DEFINITIONS

Free Cyanide:

Cyanide titratable using silver nitrate as titrant with potassium iodide and rhodamine as the end point indicators.

Weak Acid Dissociable Cyanide:

Cyanide determinable using the picric acid method with spectrophotometric determination.

Total Cyanide:

Weak acid dissociable cyanide and cyanide complexed with iron.

Thiocyanate Oxidation

Thiocyanate oxidation refers to the electro-oxidation of thiocyanate as set out below:

$$SCN^- + 6OH^- - 4e \rightarrow SO_3^{2-} + CN^- + 3H_2O$$

TABLE IV - EXPERIMENTAL RESULTS

EXPMNT No:	SMPLE NO.	COPPER ppm	IRON ppm	FREE CN ppm	TOTAL CN ppm	WAD CN ppm	SCN ppm	TIME hrs.
CELEC #1	1	320	70	380	1059.0	864	3186	0.0
CELEC #1	2	314	72	400	1077.0	876	3137	4.0
CELEC #1	3	298	70	435	1042.5	847	3040	9.0
CELEC #1	4	288	70	410	1027.5	832	2956	11.0
CELEC #2	5	320	67	370	1040.0	853	2851	0.0
CELEC #2	6	304	68	395	1078.9	889	2829	4.0
CELEC #2	7	284	70	435	1058.5	863	2779	6.5
CELEC #2	8	270	71	470	986.3	788	2749	9.0
CELEC #2	9	252	71	485	970.3	772	2709	11.0
CELEC #3	10	314	69	375	1004.7	812	2967	0.0
CELEC #3	11	308	69	390	942.7	750	2904	4.0
CELEC #3	12	276	69	455	976.7	784	2813	6.5
CELEC #3	13	252	70	480	940.5	745	2729	9.0
CELEC #3	14	232	69	465	944.7	752	2682	11.0
CELEC #4	15	314	74	330	1063.7	857	2933	0.0
CELEC #4	16	288	75	355	981.5	772	2761	4.0
CELEC #4	17	262	74	405	1013.7	807	2703	6.5
CELEC #4	18	244	72	420	932.1	731	2635	9.0
CELEC #4	19	224	74	440	913.7	707	2596	11.0
CELEC #5	20	306	54	324	1003.8	853	2882	0.0
CELEC #5	21	300	54	412	1062.8	912	2784	3.0
CELEC #5	22	288	50	458	1074.7	935	2703	5.5
CELEC #5	23	284	46	505	1088.5	960	2636	8.0
CELEC #5	24	278	46	572	1174.5	1046	2604	11.0
CELEC #5	25	272	44	597	1186.9	1064	2489	12.3

TABLE IV - EXPERIMENTAL RESULTS Cont'd

EXPMNT No:	SMPLE NO.	COPPER ppm	IRON ppm	FREE CN ppm	TOTAL CN ppm	WAD CN ppm	SCN ppm	TIME hrs.
CELEC #6A	26	328	60	309	1031.6	864	3019	0.0
CELEC #6A	27	298	62	443	1069.2	896	3097	1.0
CELEC #6B	28	210	66	700	1157.4	973	3160	1.0
CELEC #6B	29	190	64	752	1162.8	984	3179	1.5
CELEC #7	30	332	48	330	971.1	837	2875	0.0
CELEC #7	31	312	38	412	1001.1	895	2684	4.0
CELEC #7	32	306	34	484	1058.0	964	2578	6.5
CELEC #7	33	282	36	572	1121.6	1021	2535	9.5
CELEC #7	34	302	38	572	1156.1	1050	2489	12.0
CELEC #8	35	328	90	-	989.4	738	3140	0.0
CELEC #8	36	306	87	-	1052.0	809	2997	3.0
CELEC #8	37	288	80	-	1067.5	844	2974	6.0
CELEC #8	38	270	81	-	1099.2	873	2826	9.0
CELEC #8	39	266	83	-	1118.8	887	2769	11.0

TABLE V - DERIVED EXPERIMENTAL RESULTS

EXPMT No:	TIME (h)	Change in Mass of Analyte in Test Solution Cu mg	FREE CN mg	TOTAL CN mg	WAD CN mg	SCN mg
CELEC #1	4	- 30	+100	+ 90	+ 60	- 245
CELEC #1	9	-110	+275	- 85	- 85	- 730
CELEC #1	11	-160	+150	-158	-160	-1150
CELEC #2	4	- 78	+123	+191	+176	- 108
CELEC #2	6.5	-176	+318	+ 78	+ 49	- 353
CELEC #2	9	-245	+490	-265	-318	- 500
CELEC #2	11	-333	+564	-343	-397	- 696
CELEC #3	4	- 18	+ 45	-186	-186	- 189
CELEC #3	6.5	-108	+240	- 84	- 84	- 462
CELEC #3	9	-186	+415	-192	-201	- 714
CELEC #3	11	-246	+270	-180	-180	- 774
CELEC #4	4	- 65	+ 63	-205	-213	- 432
CELEC #4	6.5	-130	+188	-125	-125	- 575
CELEC #4	9	-175	+225	-330	-315	- 745
CELEC #4	11	-225	+225	-375	-375	- 843
CELEC #5	3	- 18	+264	+177	+177	- 294
CELEC #5	5.5	- 54	+402	+213	+246	- 537
CELEC #5	8	- 66	+543	+255	+321	- 738
CELEC #5	11	- 84	+744	+513	+579	- 834
CELEC #5	12.3	-102	+819	+549	+633	-1179

TABLE V - DERIVED EXPERIMENTAL RESULTS Cont'd

EXPMT No:	TIME (h)	Change in Mass of Analyte in Test Solution Cu mg	FREE CN mg	TOTAL CN mg	WAD CN mg	SCN mg
CELEC #6A	1	- 90	+402	+111	+ 96	+ 234
CELEC #6B	1	-264	+771	+267	+231	+ 189
CELEC #6B	1.5	-324	+927	+285	+264	+ 246
CELEC #7	4	- 60	+249	+ 90	+174	- 573
CELEC #7	6.5	- 78	+462	+261	+381	- 891
CELEC #7	9.5	-150	+726	+453	+562	-1120
CELEC #7	12	- 90	+726	+555	+639	-1158
CELEC #8	3	- 66	-	+189	+213	- 429
CELEC #8	6	-120	-	+237	+318	- 498
CELEC #8	9	-174	-	+330	+405	- 942
CELEC #8	11	-186	-	+390	+447	-1113

DISCUSSION

Flow Rate:

Copper Deposition

Flow rate did not significantly effect the rate of copper deposition. This is to be expected as the deposition at the current densities employed is likely to be kinetically controlled, rather than controlled by diffusion through a boundary layer at the electrode surface. Fig 1. compares the removal of copper from solution at a high flow rate (Expts.1 & 2) with its removal at a lower flow rate (Expt. 4).

Cyanide Oxidation

Cyanide oxidation was greater at lower flow rates. This is shown in Figs. 3 and 6. The lower flow would result in a less efficient transfer of the species being produced at the electrode surface. The oxidation of SCN^-, which is occuring at the electrode surface produces an increased CN^- level and a reduced pH both effects would increase the oxidation rate of cyanide.

Thiocyanate Oxidation

The oxidation of thiocyanate can be seen in Fig. 2 to increase at a lower flow rate.

Current Density:

Copper Deposition

At ambient temperature a reduction of current density results in a small reduction in the plating rate of copper.(see Fig. 16.) However, at a higher temperature increasing the current density results in a three fold increase in the plating rate. (see Fig. 12. Expts. 6A and 6B)

Cyanide Oxidation

At ambient temperature increasing current density increases the rate of cyanide oxidation. This cyanide is presumably oxidised to cyanate.(see Fig. 17). The shape of this graph is presumably due to the fact that two competing reactions are taking place, the production of cyanide by the oxidation of thiocyanate and the removal of cyanide by its oxidation.

Thiocyanate Oxidation

The oxidation of thiocyanate increases with increasing current density as seen in Fig. 18.

Temperature:

Copper Deposition

The rate of deposition of copper can be increased from 0.025 lb/kWh to 0.325 lb/kWh by increasing the temperature from 25^{o} C to 65^{o} C. (see Fig. 12.)

Free Cyanide Regeneration

The overall rate of free cyanide regeneration can be increased from 0.29 lb/kWh to 1.58 lb/kWh by a rise in temperature from 25^{o} C to 65^{o} C. (see Fig. 14.)

Thiocyanate Oxidation

Unfortunately it is not possible to determine the effect of temperature on the electro-oxidation of thiocyanates from these experiments. Heating the barren solution from 25^{o}C to 65^{o}C over a period of 5 hours produced an increase in thiocyanate level in the solution of 670 ppm. This increase in thiocyanate level was not accompanied by a decrease in either free, total or WAD cyanide levels.

pH:

Copper Deposition

The rate of copper deposition decreased when the pH level increased. This is to be expected as at lower pH more of the cyanide is in the undissociated form i.e. as HCN and therefore not able to complexwith the copper to form the higher copper complexes which are not as readily reduced to copper. (see Fig. 4.)

Free Cyanide Regeneration

Stabilising the pH at 10.9 resulted in a substantial increase in free cyanide regeneration over similar tests at a lower pH. (see Fig. 5.)

Thiocyanate Oxidation

Stabilising the pH at 10.9 resulted in a significant increase in the rate of thiocyanate oxidation. (see Fig. 2.)

Figure. 1.

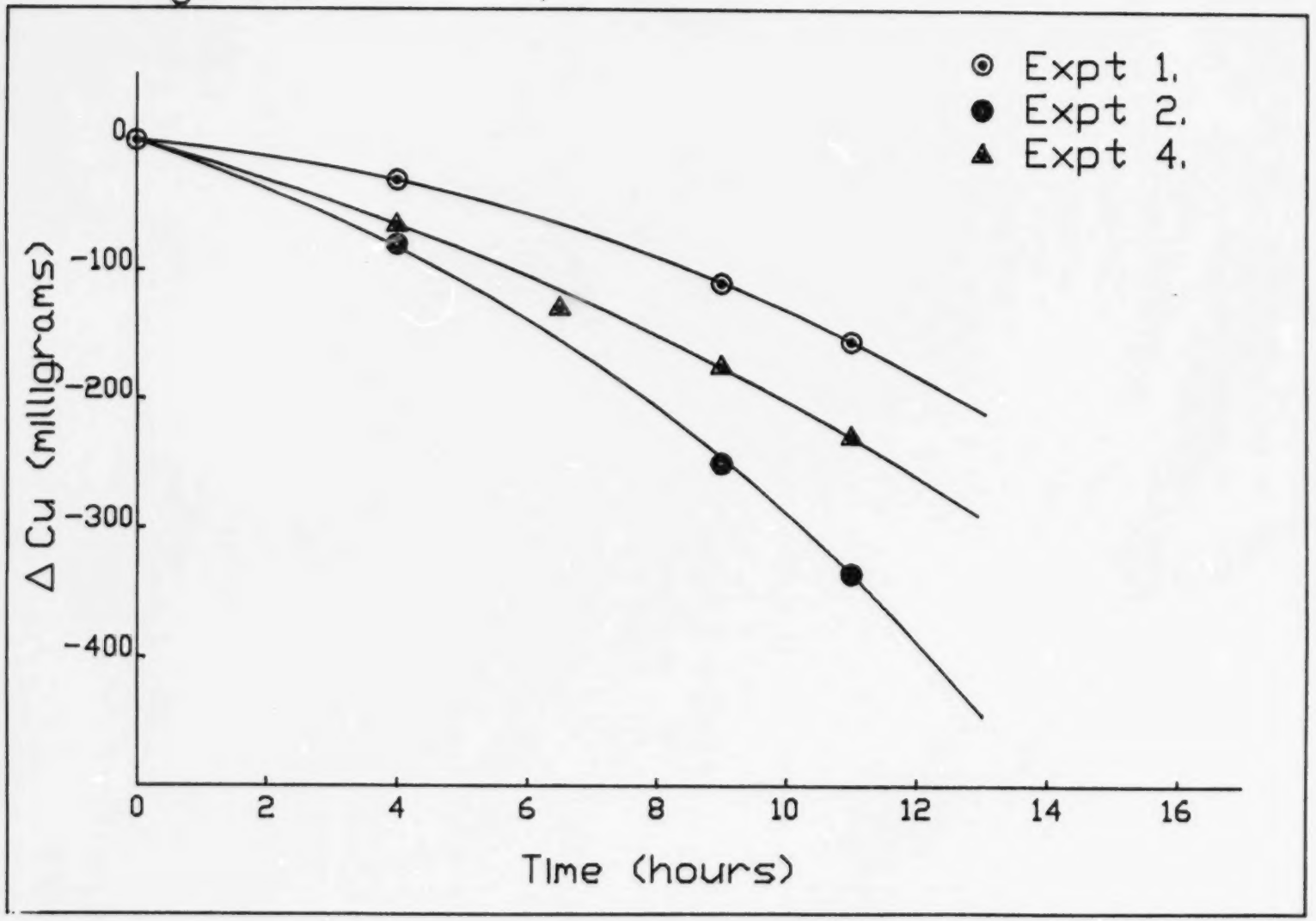

Expt 1.
Expt 2.
Expt 4.
0
-100
-200
-300
-400
Δ Cu (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 2.

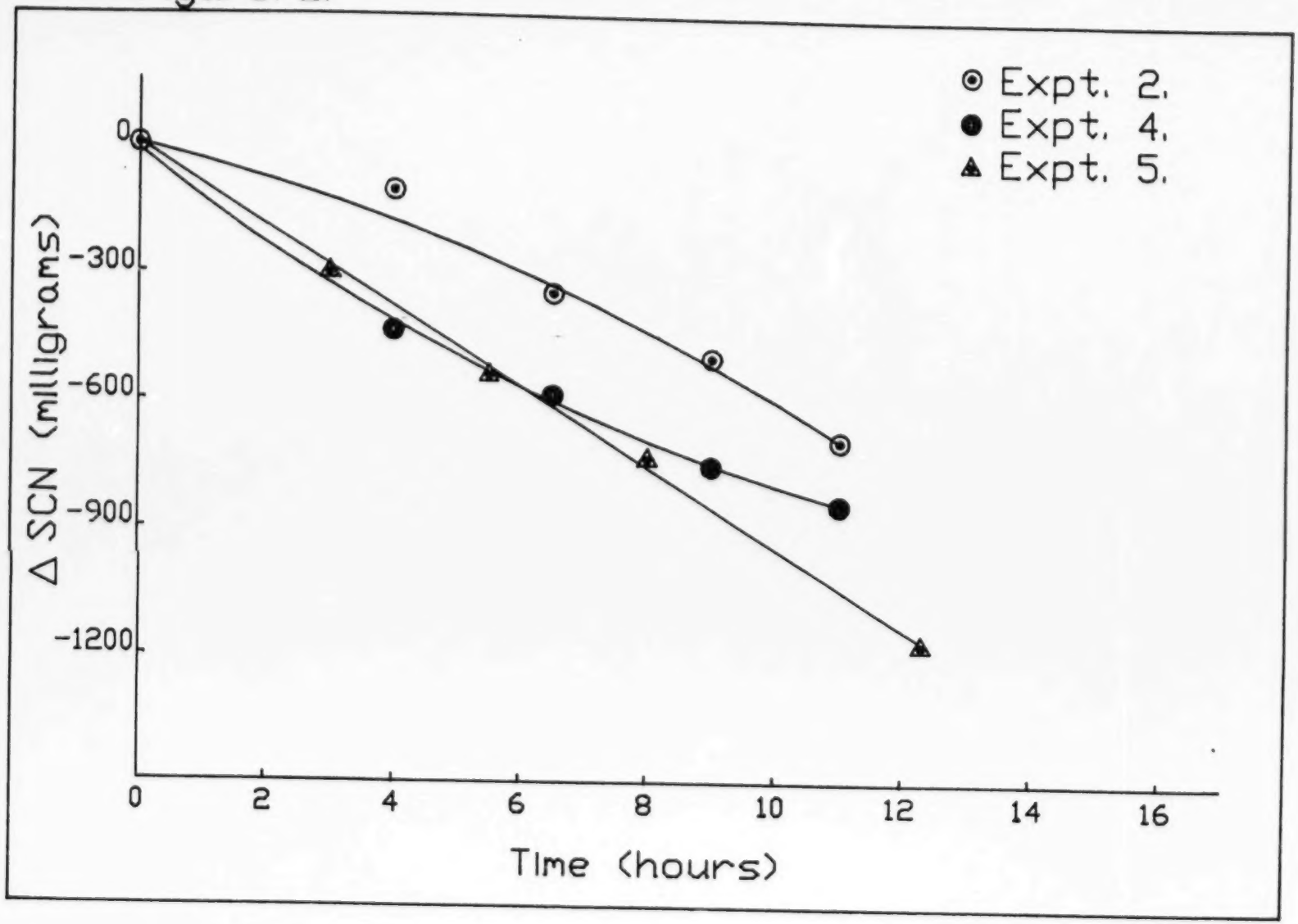

Expt. 2.
Expt. 4.
Expt. 5.
0
-300
-600
-900
-1200
Δ SCN (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 3.

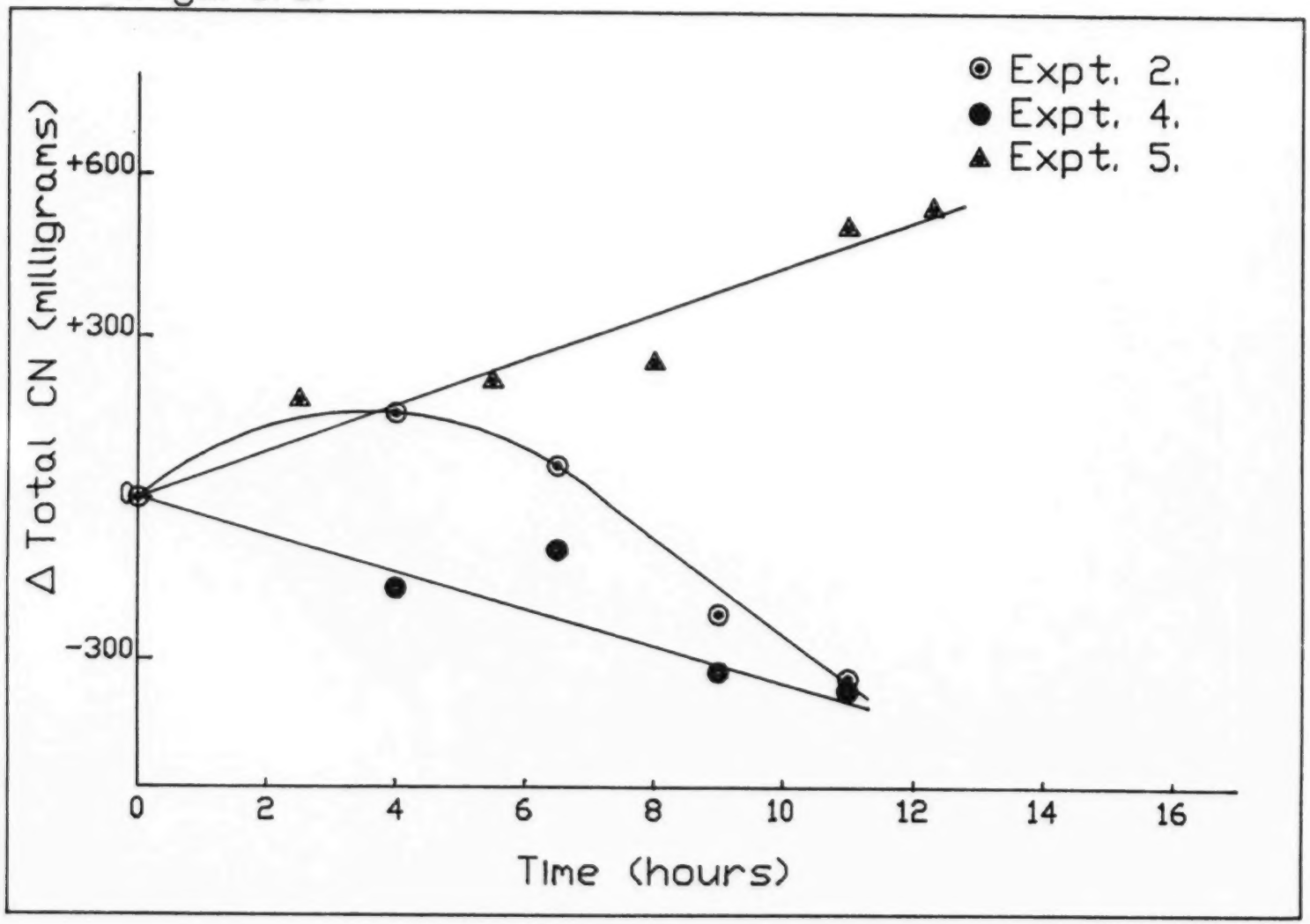

Expt. 2.
Expt. 4.
Expt. 5.
Δ Total CN (milligrams)
+600
+300
0
-300
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 4.

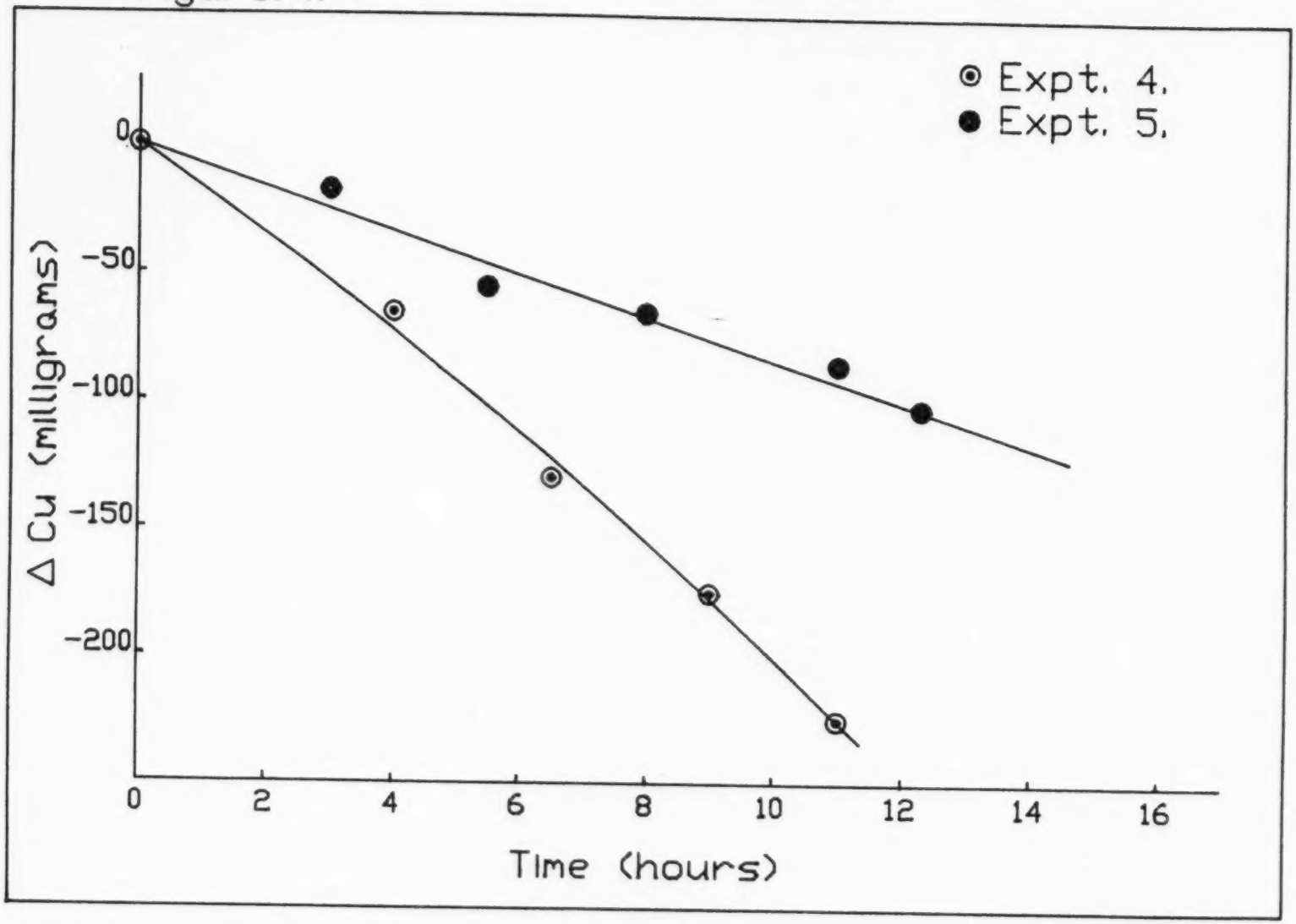

Expt. 4.
Expt. 5.
0
-50
-100
-150
-200
Δ Cu (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 5.

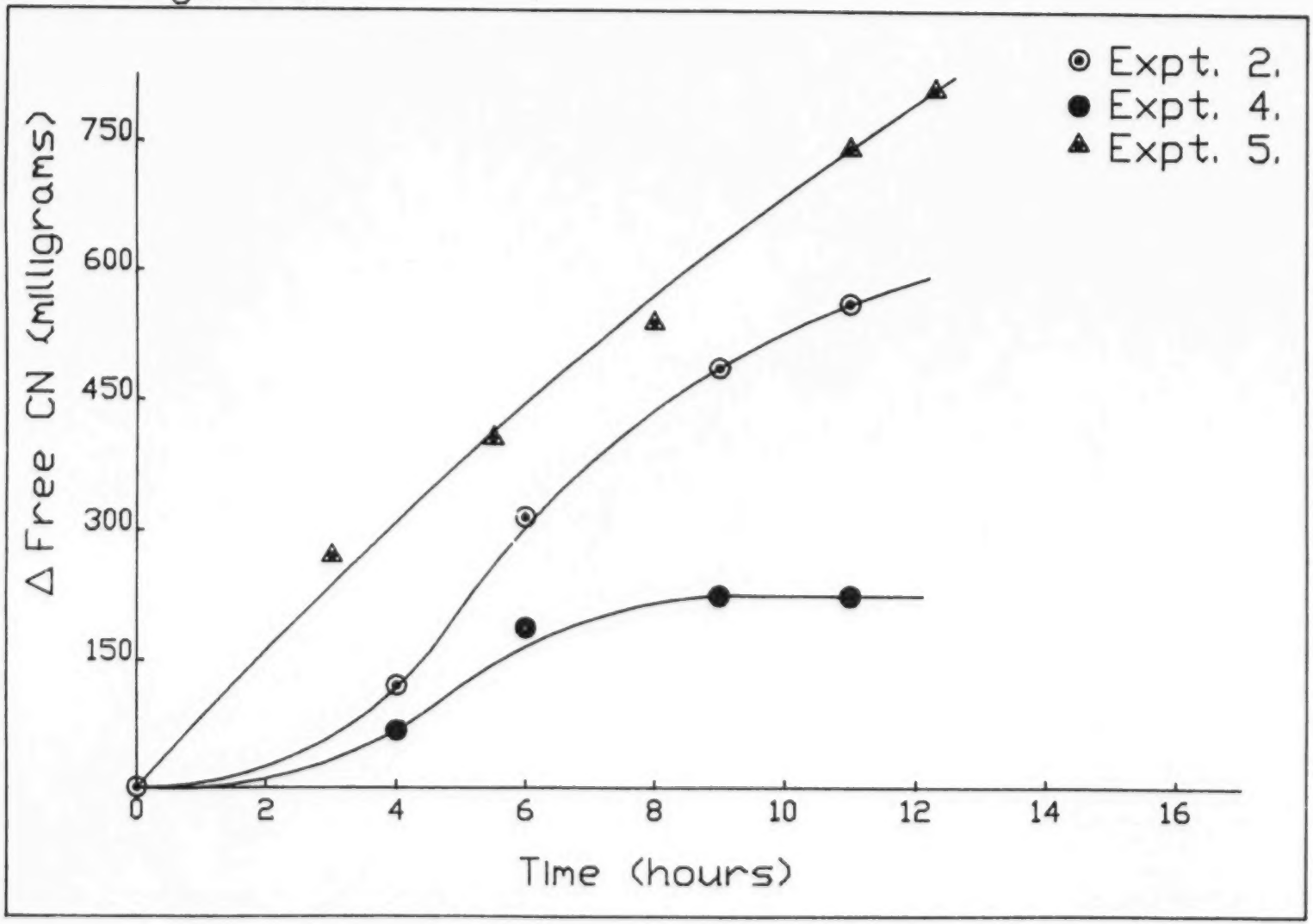

Expt. 2.
Expt. 4.
Expt. 5.
Δ Free CN (milligrams)
750
600
450
300
150
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 6.

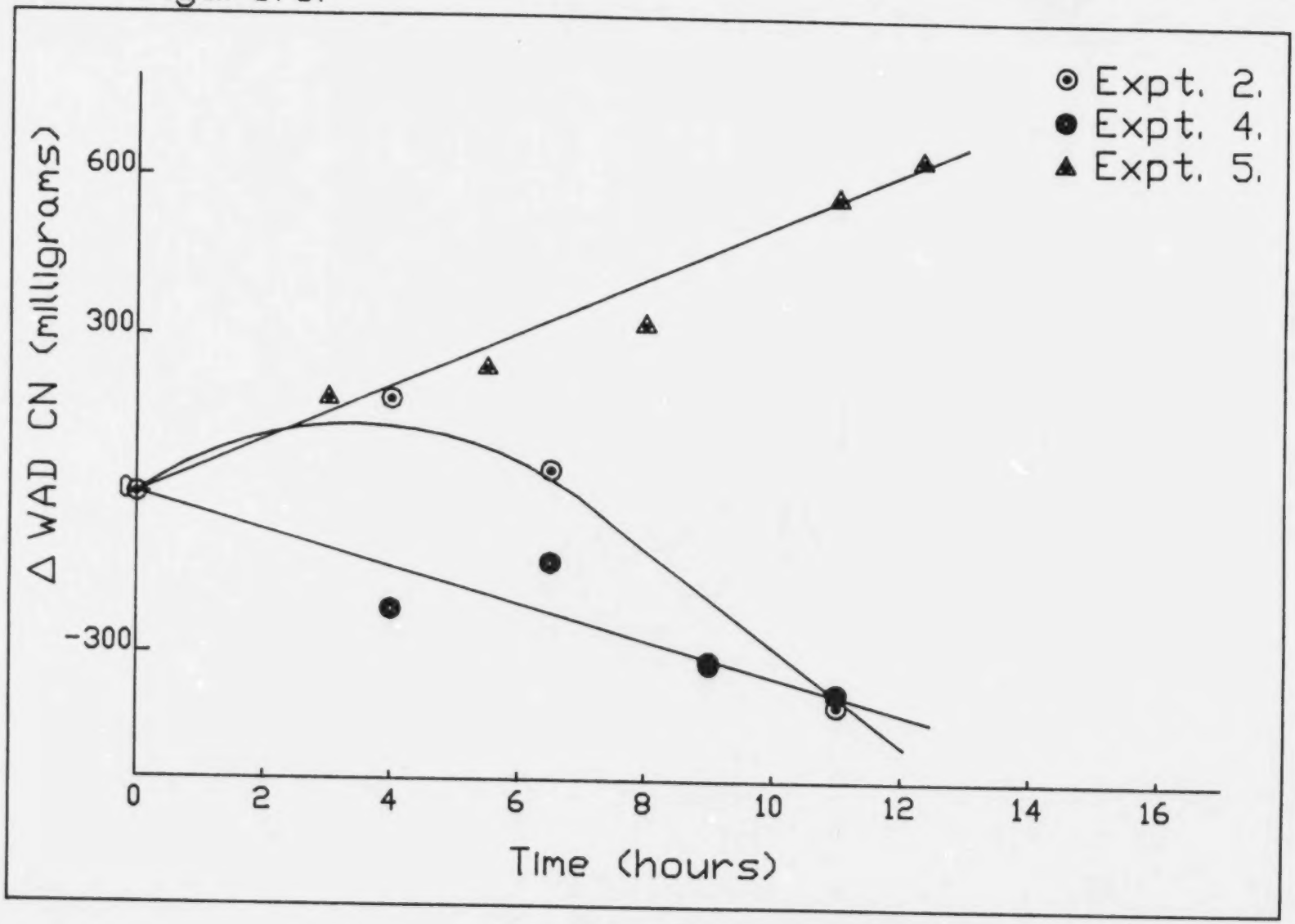

Expt. 2.
Expt. 4.
Expt. 5.
Δ WAD CN (milligrams)
600
300
0
-300
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 7.

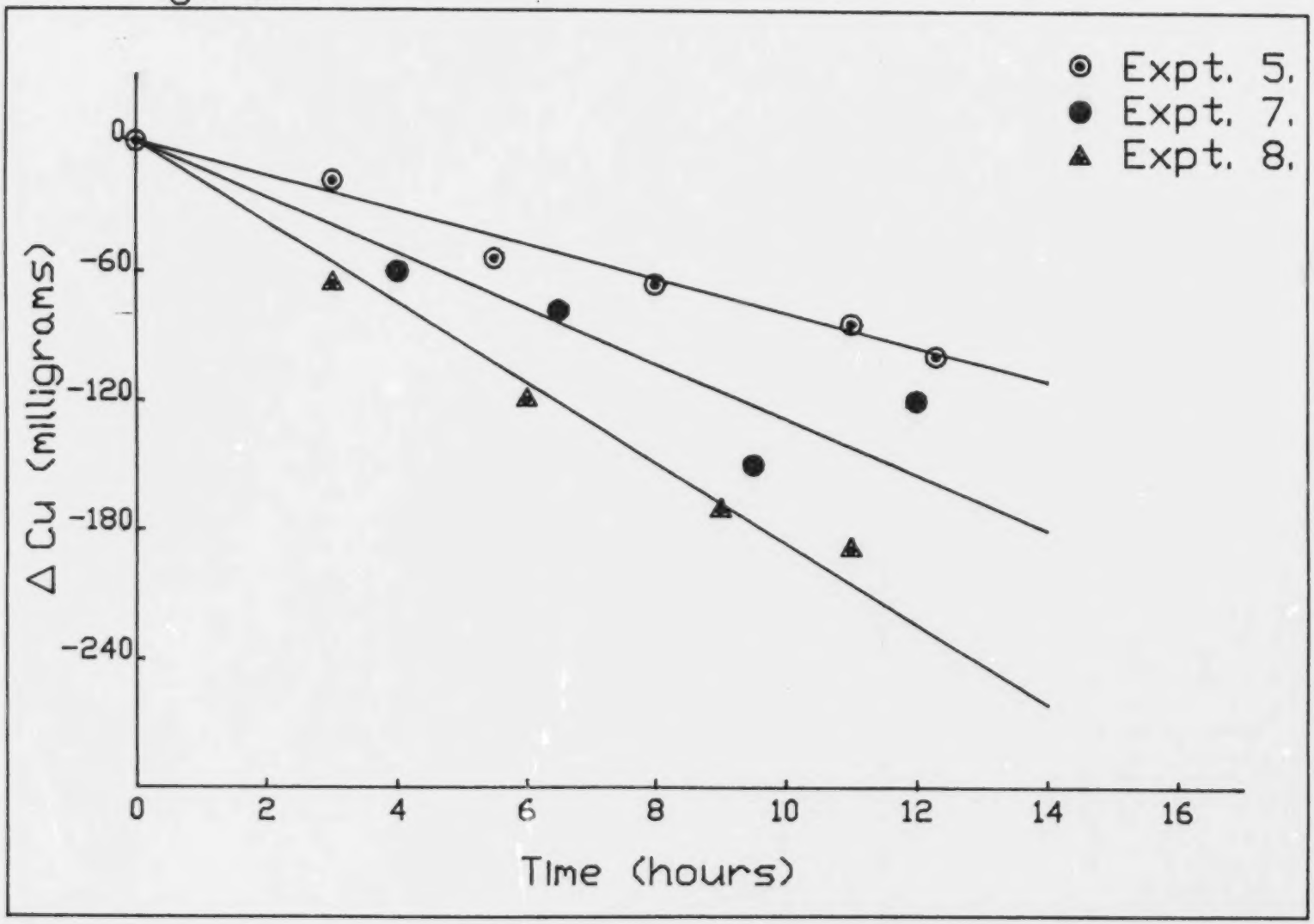

Expt. 5.
Expt. 7.
Expt. 8.
0
-60
-120
-180
-240
Δ Cu (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 8.

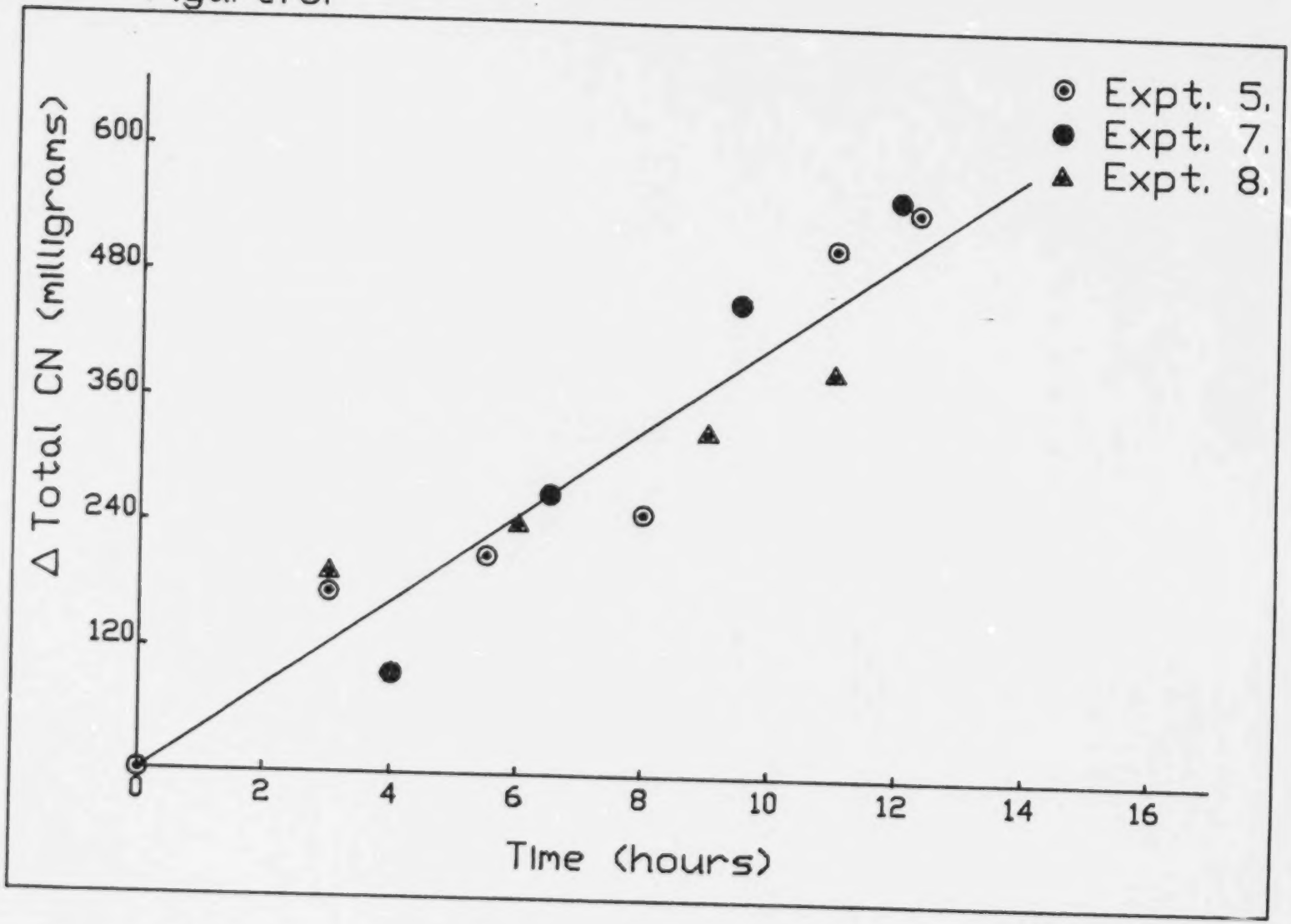

Expt. 5.
Expt. 7.
Expt. 8.
Δ Total CN (milligrams)
600
480
360
240
120
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 9.

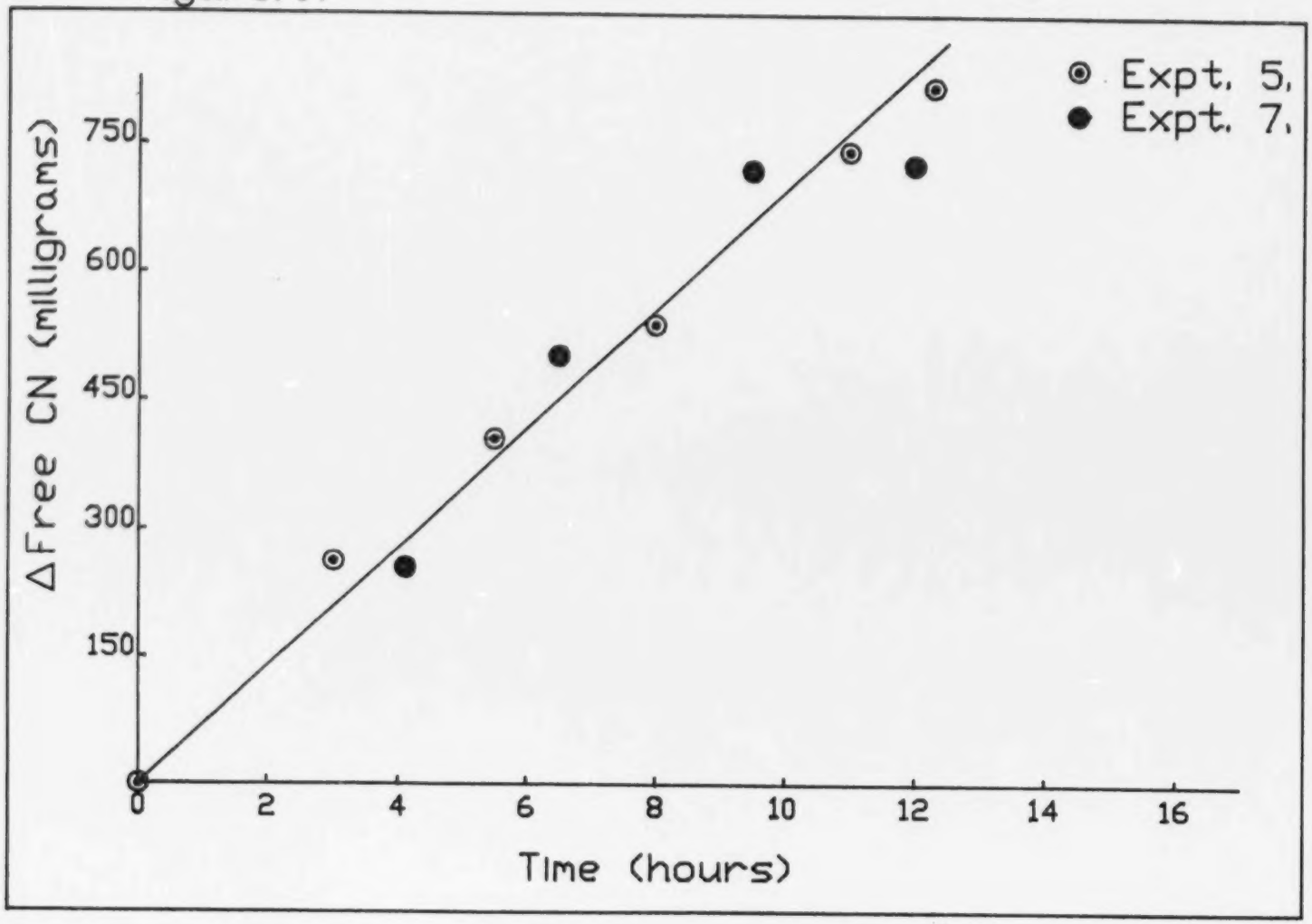

Expt. 5.
Expt. 7.
ΔFree CN (milligrams)
750
600
450
300
150
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 10.

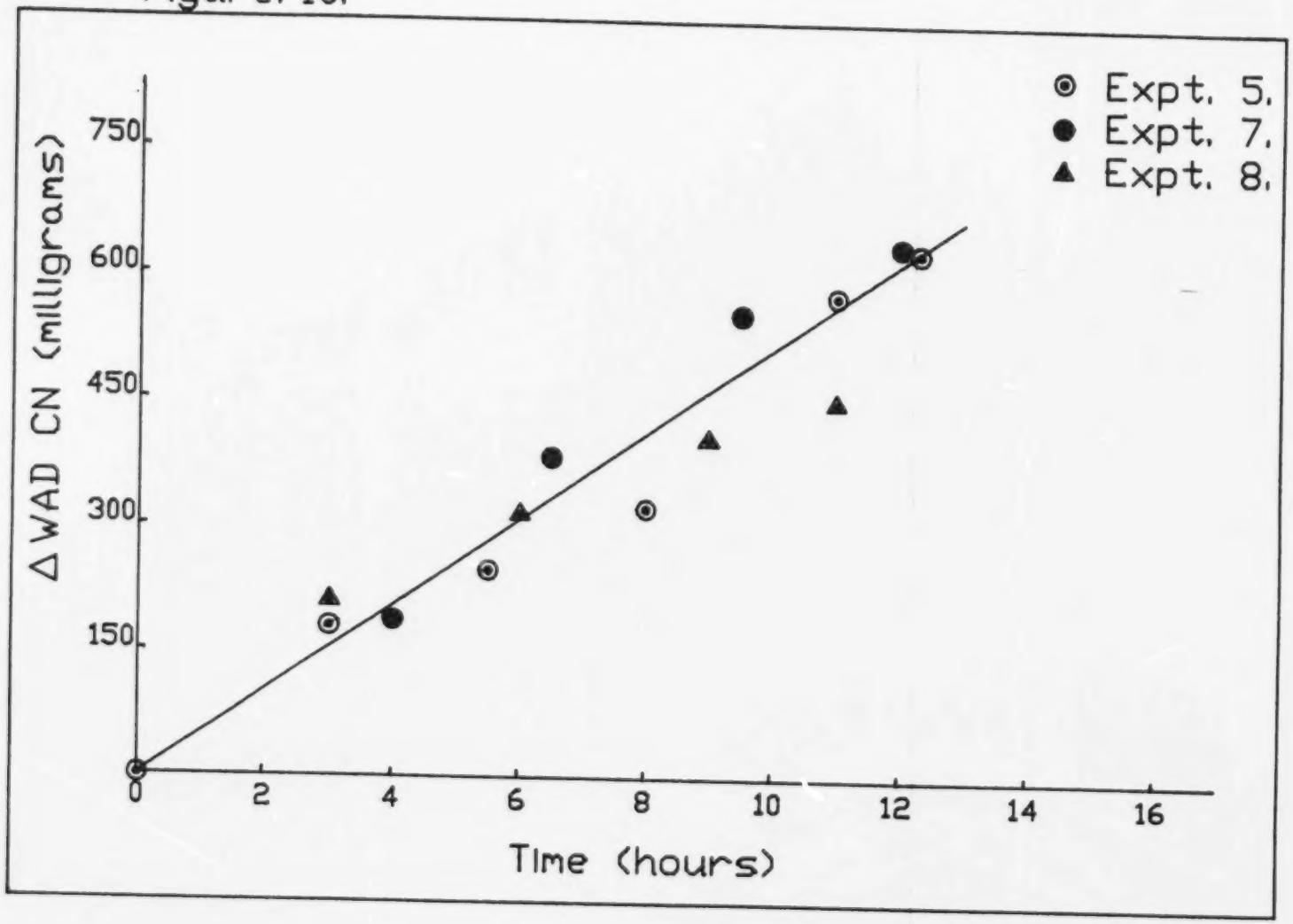

Expt. 5.
Expt. 7.
Expt. 8.
ΔWAD CN (milligrams)
750
600
450
300
150
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 11.

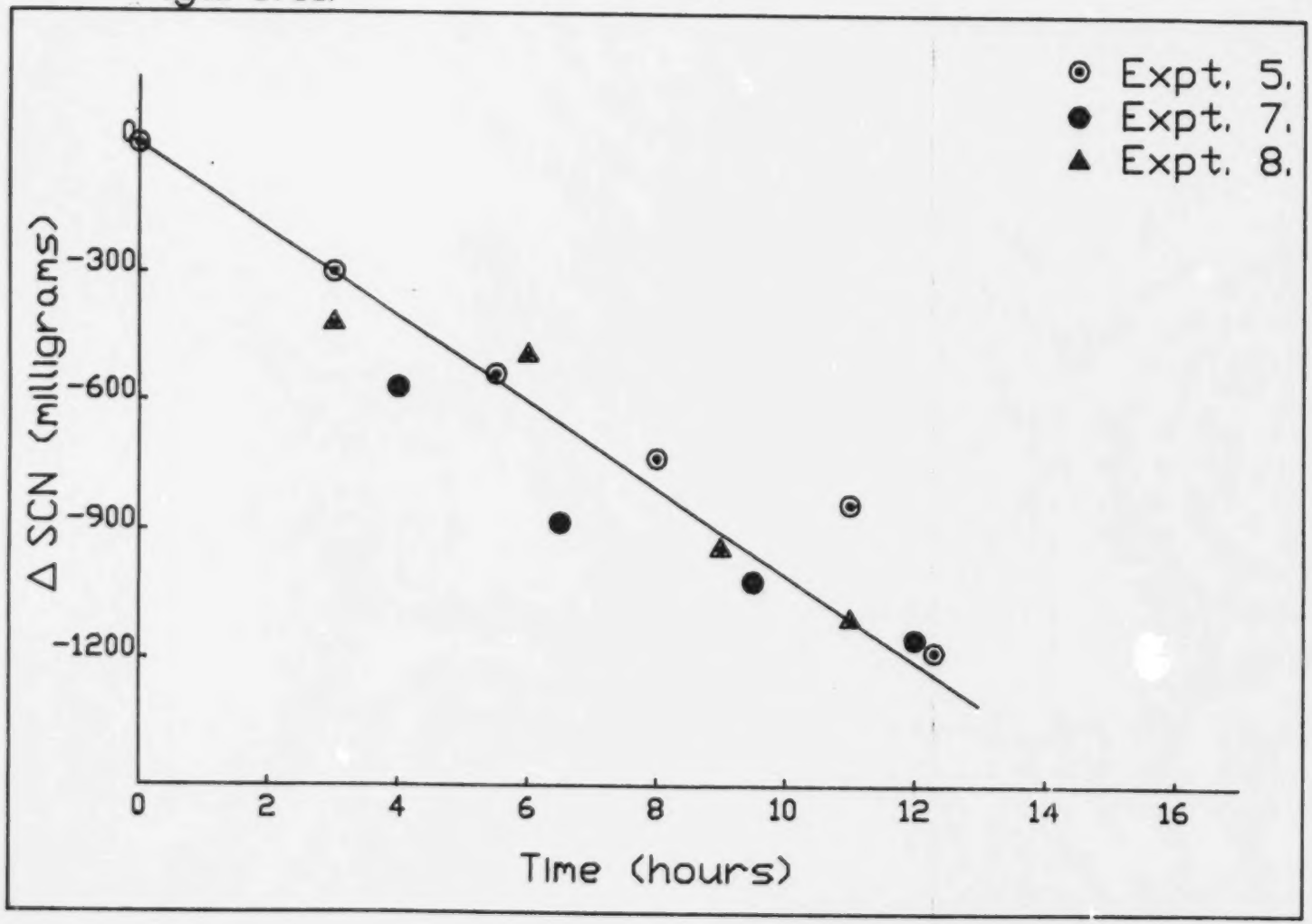

Expt. 5.
Expt. 7.
Expt. 8.
0
-300
-600
-900
-1200
Δ SCN (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 12.

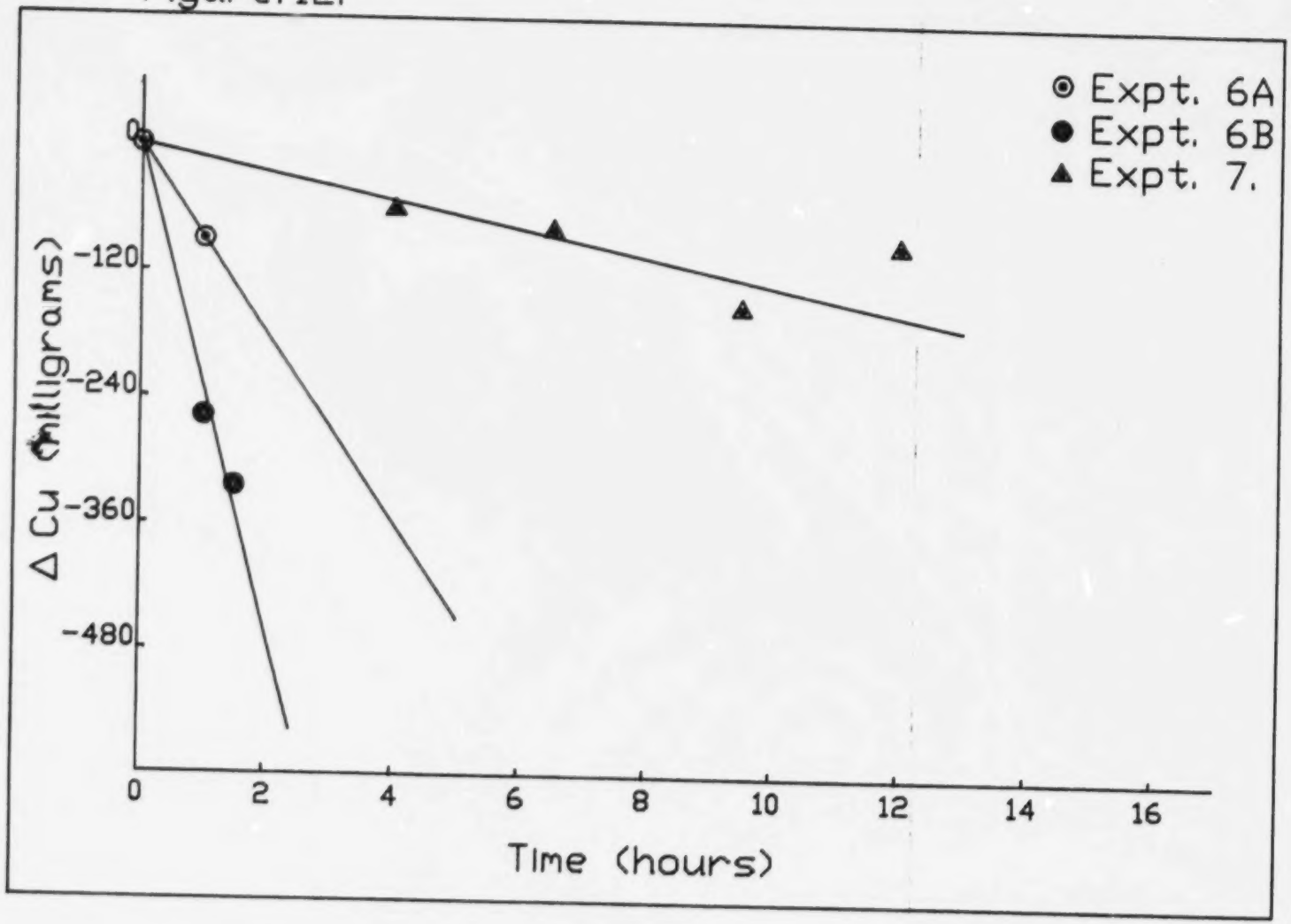

Expt. 6A
Expt. 6B
Expt. 7.
0
-120
-240
-360
-480
Δ Cu (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 13.

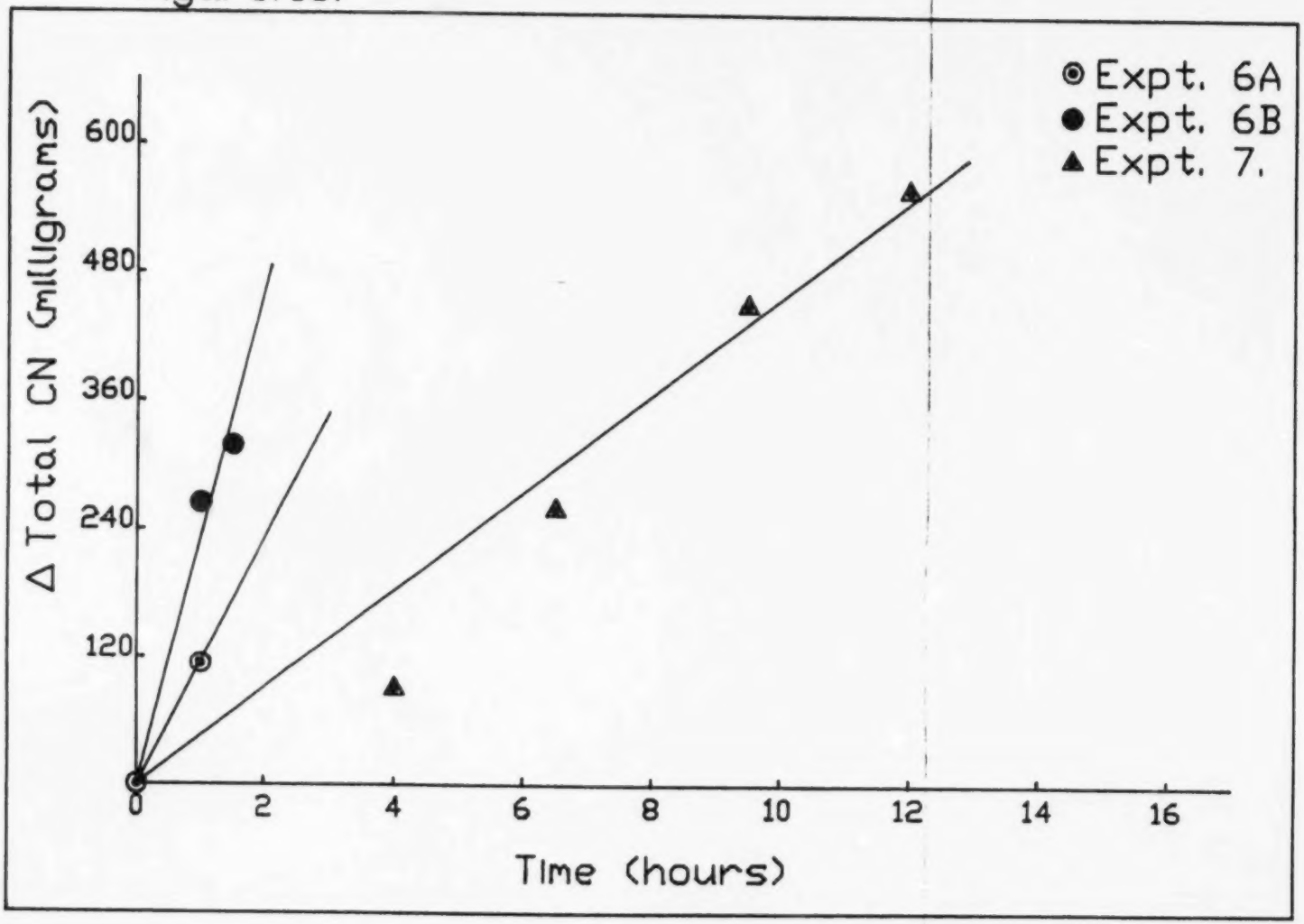

Expt. 6A
Expt. 6B
Expt. 7.
Δ Total CN (milligrams)
600
480
360
240
120
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 14.

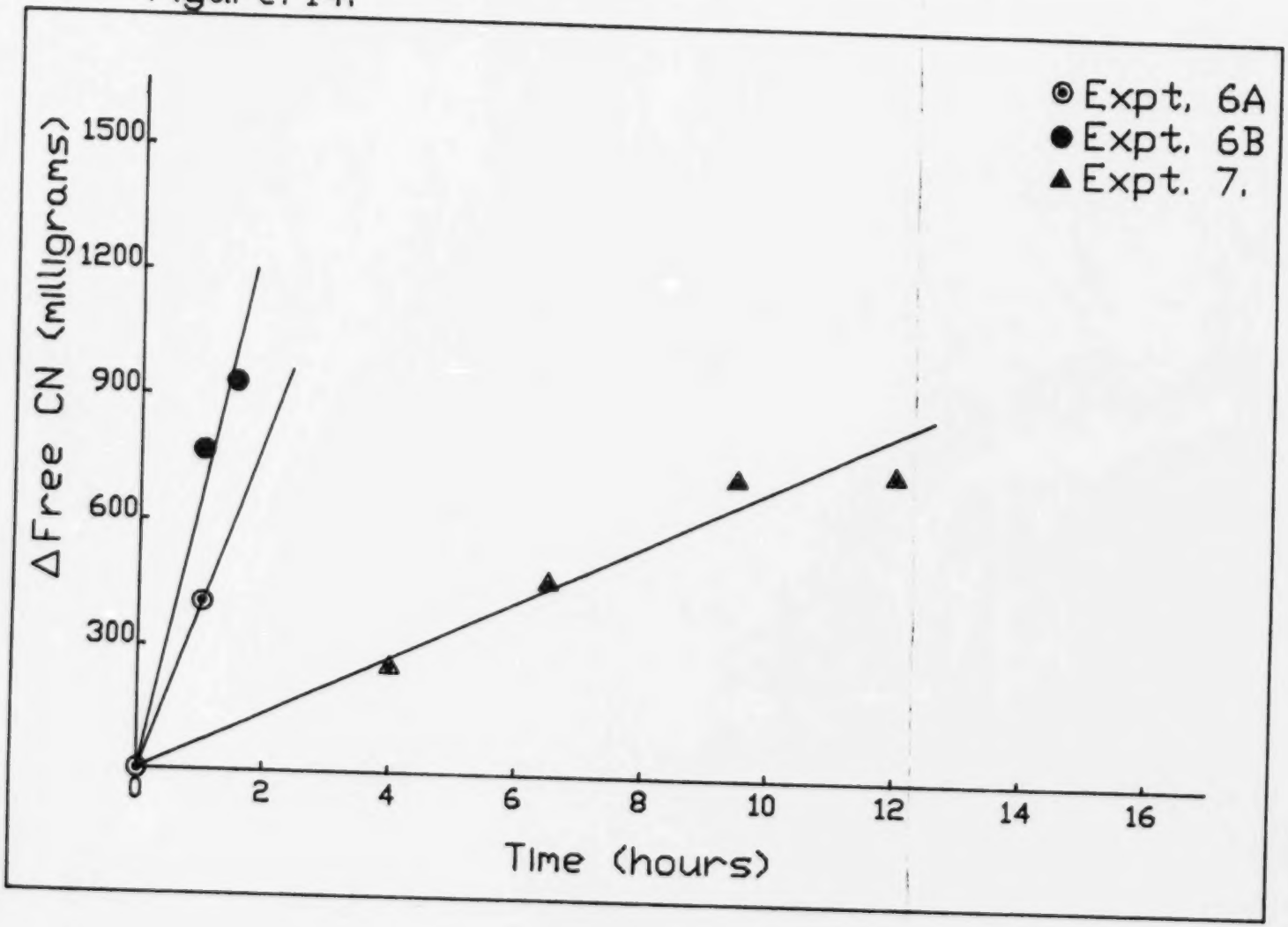

Expt. 6A
Expt. 6B
Expt. 7.
ΔFree CN (milligrams)
1500
1200
900
600
300
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 15.

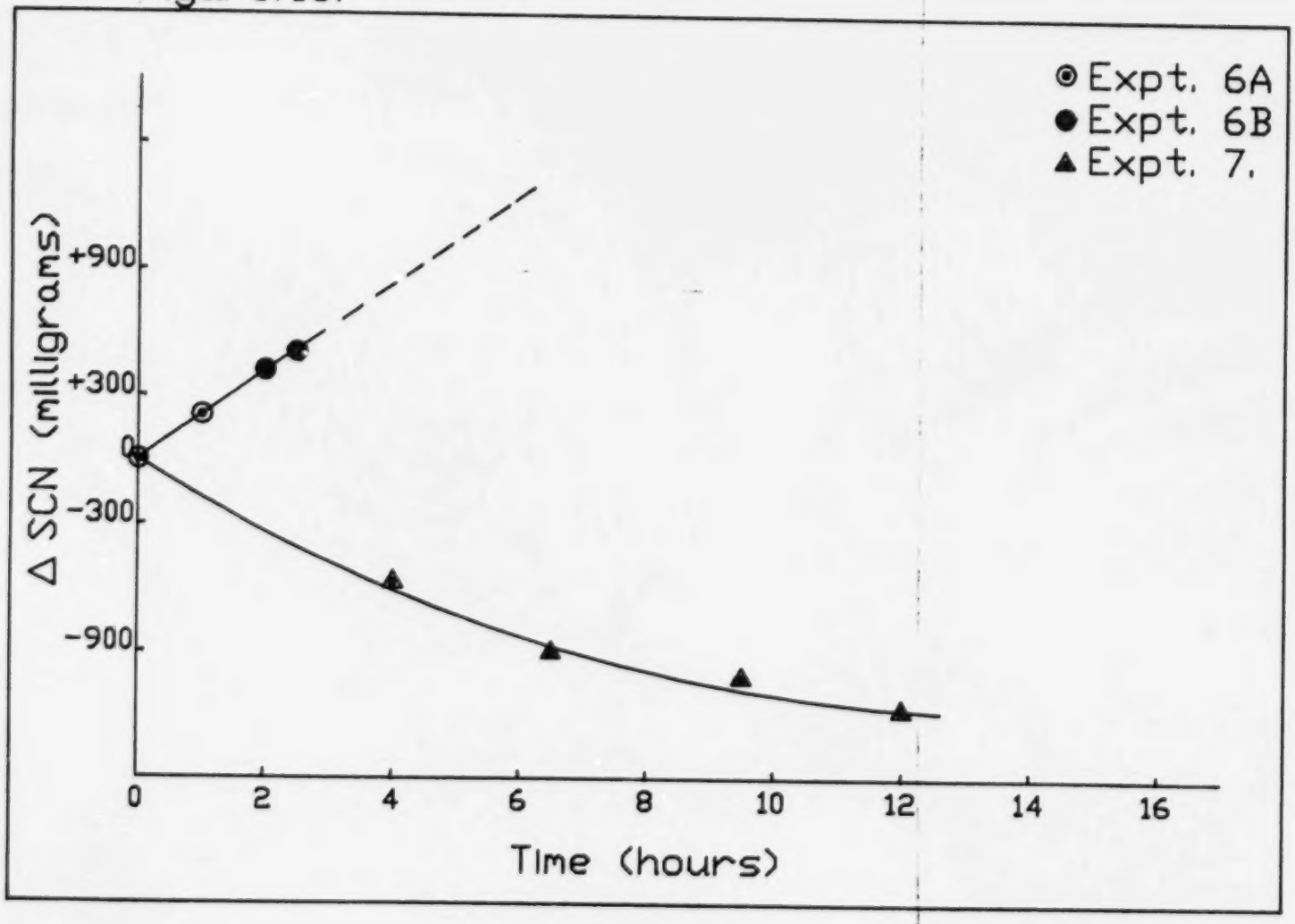

Expt. 6A
Expt. 6B
Expt. 7.
Δ SCN (milligrams)
+900
+300
0
-300
-900
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 16.

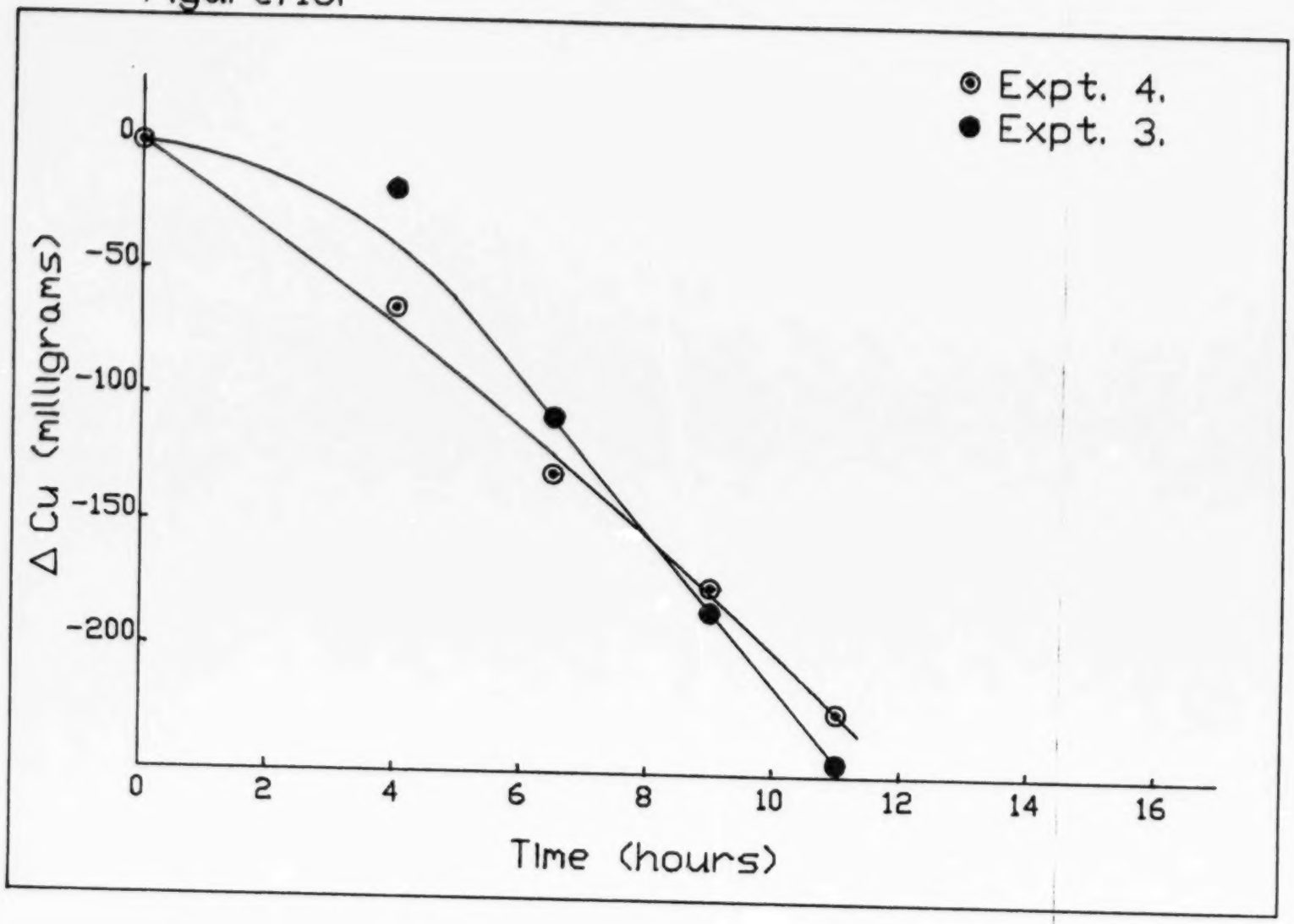

Expt. 4.
Expt. 3.
0
-50
-100
-150
-200
Δ Cu (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

Figure. 17.

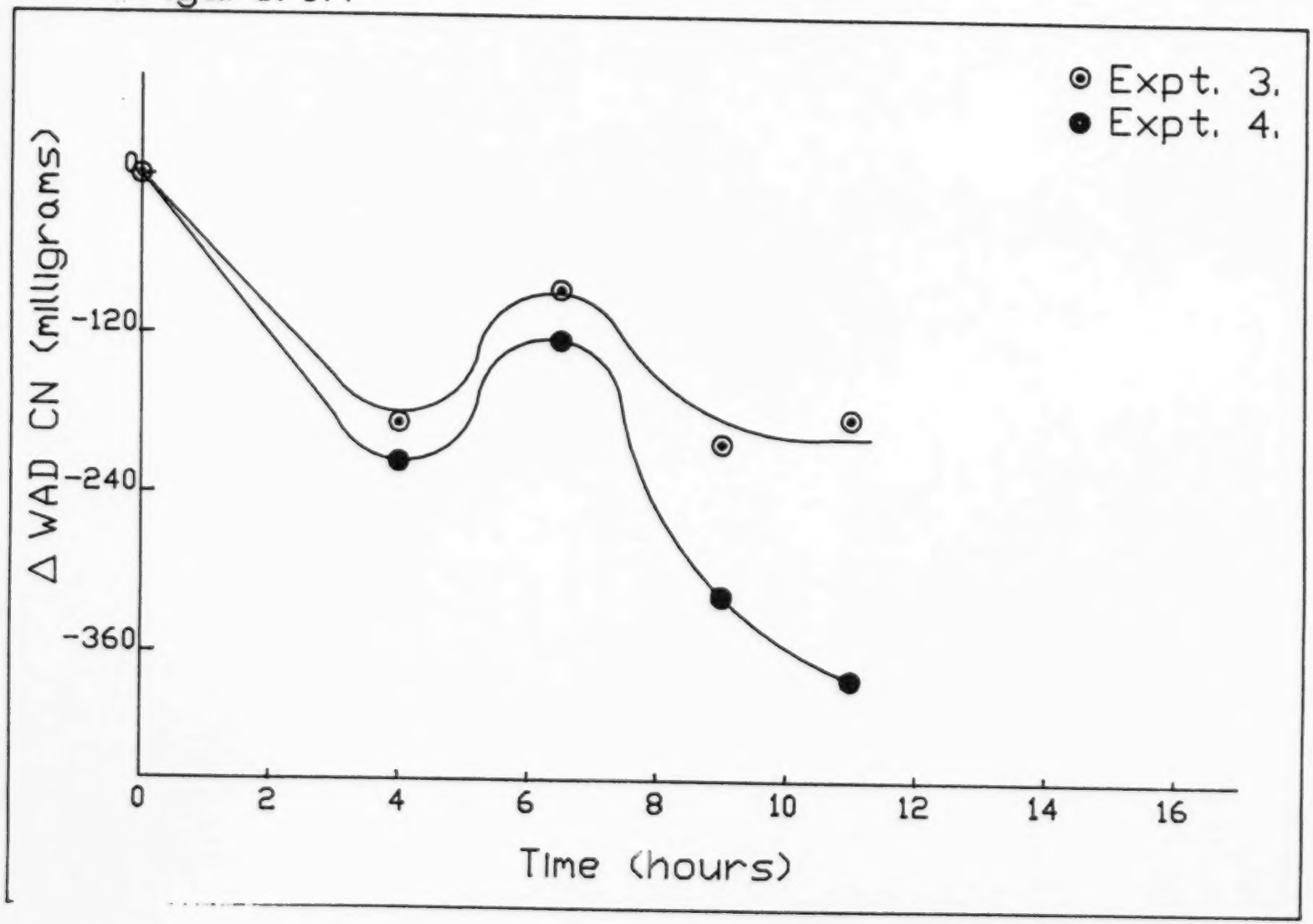
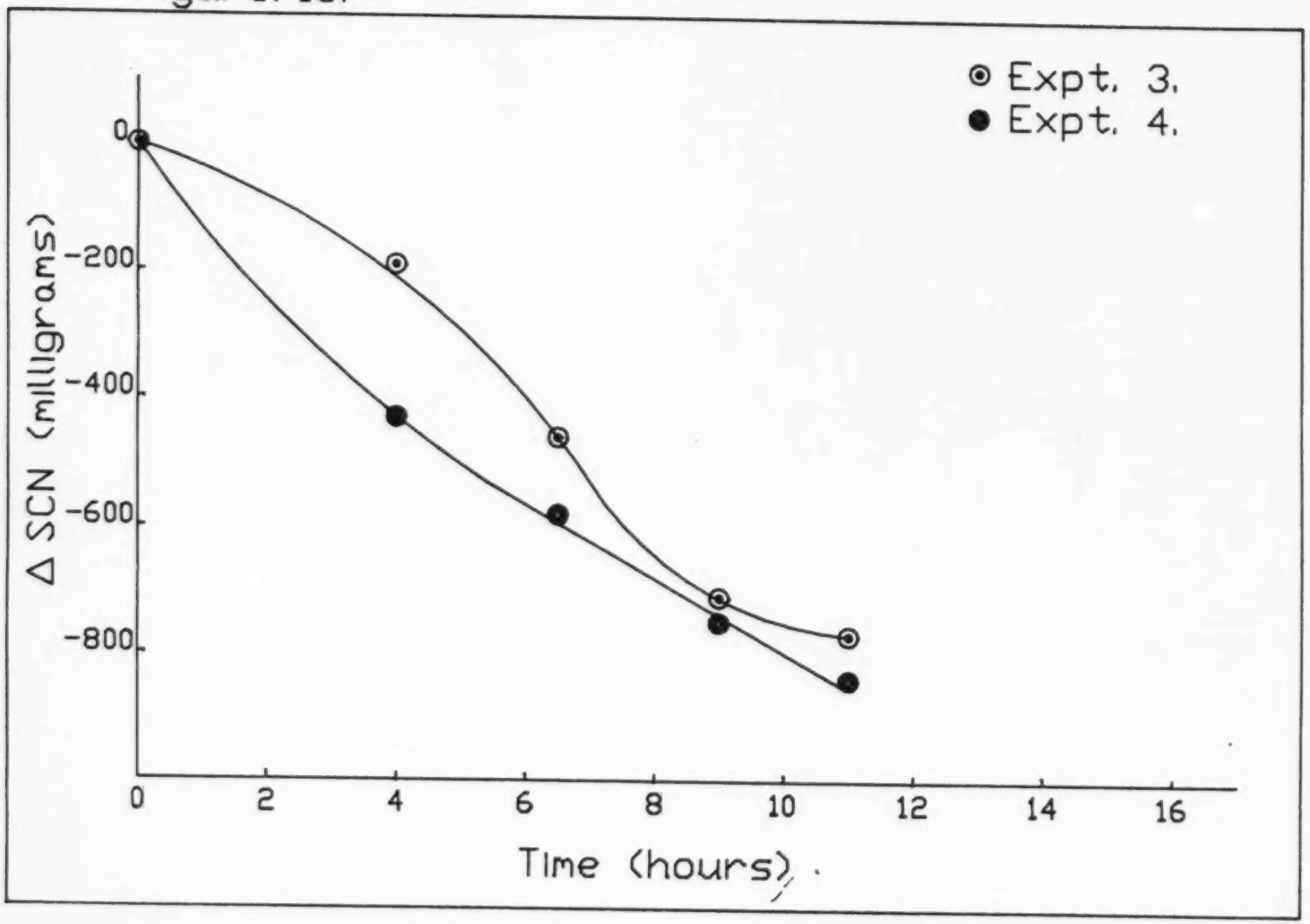

Expt. 3.
Expt. 4.
Δ WAD CN (milligrams)
0
-120
-240
-360
0
2
4
6
8
10
12
14
16
Time (hours)

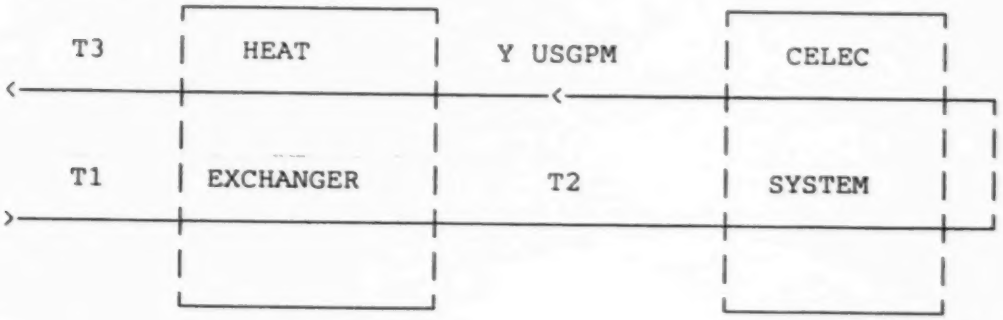
Figure. 18.


Expt. 3.
Expt. 4.
0
-200
-400
-600
-800
Δ SCN (milligrams)
0
2
4
6
8
10
12
14
16
Time (hours)

POWER

The electrolytic system consumes power. The majority of the power consumption occurs as a result of the IR drop across the cell solution. The effect of this IR drop is to increase the temperature of the solution. The power entering the solution being equal to I^2R.

By adding a simple heat exchanger as shown below, the temperature of the electrolytic system could be increased as calculated.



Efficiency of
Heat Exchanger $= (T2 - T3)/(T2 - T1) = E$

Heat Loss $= (T3 - T1) \times Y \text{ USGPM} \times 4 \times 1000 \text{ cal/min}$

$= (T3 - T1) \times Y \times 4 \times 1000 \times 4 \text{ joule/min}$

$$= \frac{(T3 - T1) \times Y \times 4 \times 1000 \times 4}{60 \times 1000} \text{ kWatts}$$

At equilibrium = Heat Gain from I^2R heating

Therefore:

$$I^{2R} = \frac{4(T3 - T1) \times Y}{15}$$

$$T3 = T1 + 3.75I^2R/Y$$

Substituting for T3 in the efficiency equation:-

$$E = (T2 - T1 - 3.75I^2R/Y) / (T2 - T1)$$

$$3.75I^2R/Y = (T2 - T1)(1 - E)$$

Therefore the rise in temperature, (T2 - T1), due to the I^2R heating taking place within the electrolytic system, can be calculated from the equation below:.

$$(T2 - T1) = 3.75I^2R/Y(1 - E)$$

Assumptions:

- .A 10 cell electrolytic system with a flow rate of 300 USGPM.
- .A power input of 320 Kilowatts.
- .A heat exchanger with an efficiency of 80%.

Then:

$$(T2 - T1) = 20^{\circ}C$$

CONCLUSION

A heat exchanger with an 80% operating efficiency could produce a $20^{\circ}C$ rise in temperature of the solution in the electrolytic system.

SYSTEM SIZE

The size of electrolytic system required for any one application could be determined by one of three factors:

i) flow rate
ii) copper removal rate
or iii) current density

i) Flow rate

If the recirculating flow required to remove copper from solution determines that NM^2 of cathode surface area is required and N is greater than the number of anodes required to oxidize the thiocyanate to cyanide then the flow rate could be the determining factor in the size of the system.

ii) Copper removal rate

If large amounts of copper are being removed from solution then the ability of the electrode to hold copper becomes important and may very well determine the size of the system as the frequency of electrode changing should be limited to once or twice a day.

iii) Current density

If the main economic driving force of the installation is oxidation of thiocyanates to cyanide then the current required to sustain the oxidation may very well determine the system size.

In the three cases following, where profitability is discussed these factors above have combined to produce the postulated performance and increases in performance suggested.

PROFITABILITY

Three cases will be estimated for profitability:

1) CASE A - No heat exchanger, system to operate at ambient temperature.

2) CASE B - Heat exchanger of 80% efficiency employed producing a 20°C rise in temperature and a doubling of efficiency, compared to Case A.

3) CASE C - Heat exchanger of 80% efficiency employed plus heat input of 400 kW at 80% efficiency. Producing a 40°C rise in temperature, a six-fold increase in copper a four fold increase in free cyanide regeneration, compared to Case A.

SYSTEM SIZE	A	B	C
REGENERATION CELLS:	10	7	3
STRIPPING CELLS:	2	4	5
POWER: kW regen. cell	320	325	170
strip cell	4	8	10
pumps	10	10	10
misc.	3	3	3
heat gen.	___	___	400
Total	337	346	593
Cost @ $0.028/kWh	$226/day	$233/day	$398/day
Maintenance @ approx. 5% of capital cost/year	$226/day	$226/day	$144/day
Labour @ $160/man day	$160/day	$320/day	$320/day
TOTAL:	**$612/day**	**$779/day**	**$862/day**

Given the above parameters the costs and revenues are shown below for the three cases

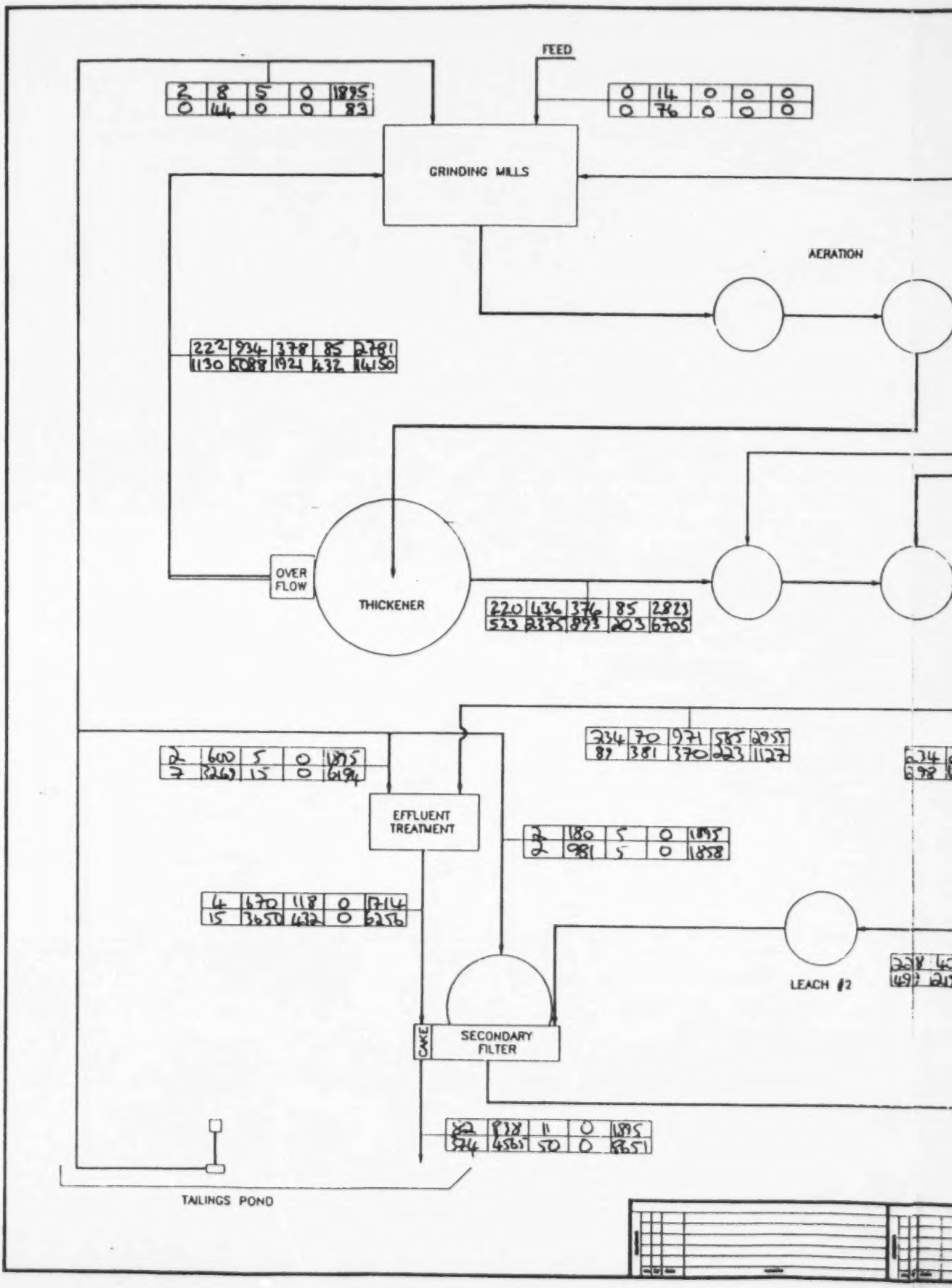
	A	B	C
COPPER PRODUCTION: (lb/day)	207	421	680
FREE NaCN PRODUCTION: (lb/day)	2,227	4,500	4,500
REVENUES:			
Copper @ 1.20 /lb.	248	505	816
NaCN regenerated @ $1.00/lb.	2,227	4,500	4,500
Reduction in NaCN destruction use @ $1.00/lb.	2,227	4,500	4,500
TOTAL REVENUES:	$4,702/day	$ 9,505/day	$ 9,816/day
PROFITABILITY:			
REVENUES	4,702	9,505	9,816
LESS COSTS:	612	779	862
PROFIT/DAY:	$4,090	$8,726	$ 8,954
PER YEAR:	$1,492,850	$3,184,990	$3,268,210
ESTIMATED CAPITAL COST:	$1,950,000	$1,650,000	$1,050,000

RECOMMENDATIONS

1) A CELEC system capable of treating 12% of the barren flow be installed for test purposes.

2) A heat exchanger (approx. cost. $1,800.00) be installed on the system to retain the heat created by the system.

Following the above recommendations would result in the installation of a type B system, i.e. one utilising its internal power only to produce a rise in solution temperature.


FEED
GRINDING MILLS
AERATION
OVER FLOW
THICKENER
EFFLUENT TREATMENT
LEACH #2
CIP
SECONDARY FILTER
TAILINGS POND

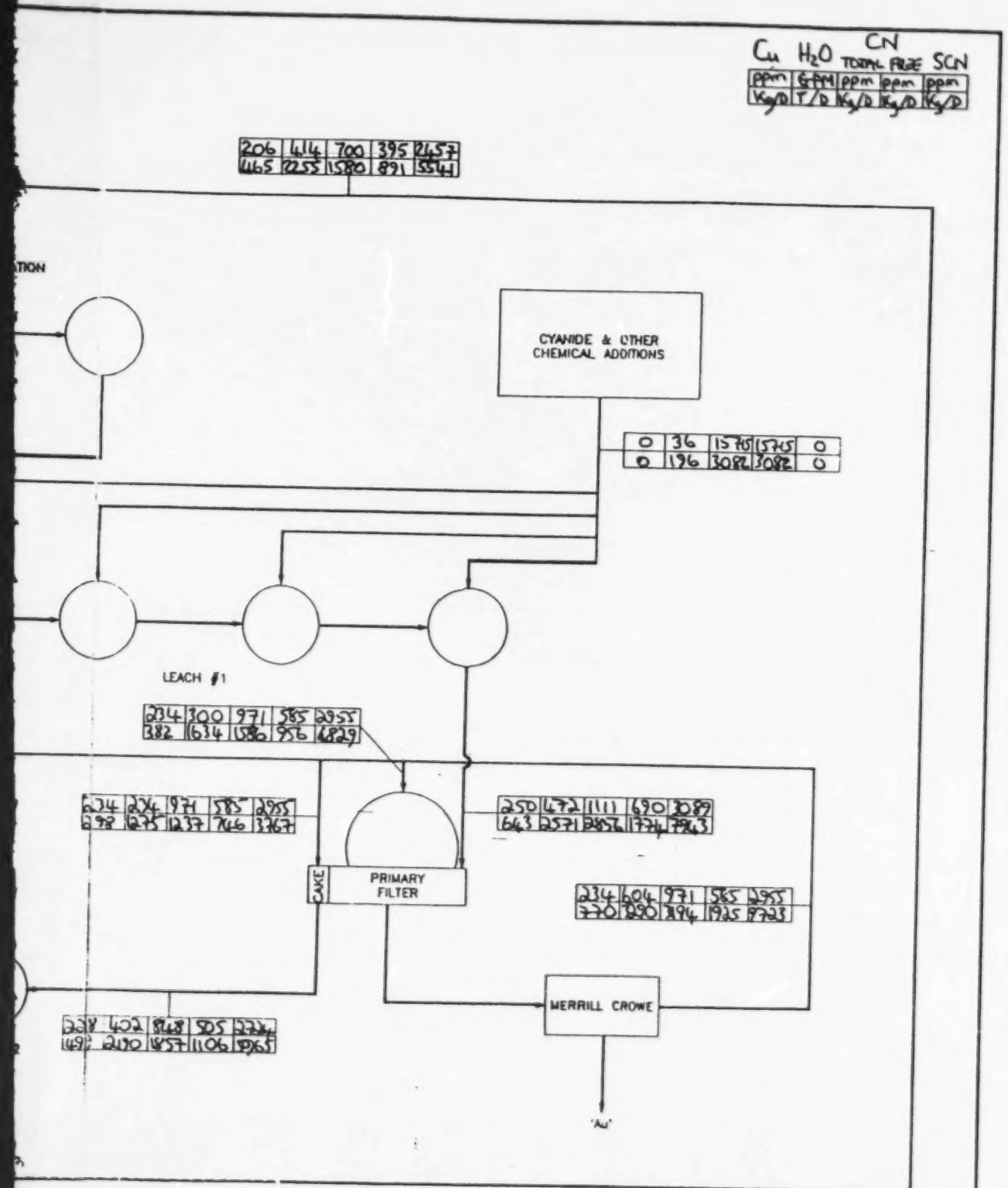


FIGURE A

OROCON

NICKEL PLATE PROCESS FLOWSHEET

CEL-FL2

△